Should App Self-Management Mean Self-Control? A Quantiative Study on App Supported Diabetes Self-Management

Lukas Reineke[a], Ursula Hübner[a], Saskia Kröner[a], Jan-David Liebe[a,b]

[a]Health Informatics Research Group, University AS Osnabrück, Germany
[b]Institute of Medical Informatics, UMIT - Private University for Health Sciences,
Medical Informatics and Technology, Hall in Tyrol, Austria

Abstract

Apps have been attested to empower patients regarding disease self-management through numerous studies. However, it is still unclear what factors determine the perception of patients whether an app is a useful tool for this purpose. A multiple regression model that was informed by the Technology Acceptance Model (TAM 2) was tested based on the answers of 235 app users with Diabetes type 1 or 2. The model accounted for 59.2% of the variance of the perceived degree of self-management. Factors belonging to the relevance-usefulness-quality complex as well as factors reflecting the patient's self-control were found to be significant in the model. Patient demographics, i.e. age, gender, app experience and type of Diabetes did not play any significant role. In conclusion, this study raises the question whether apps should be designed to strengthen self-management in the sense of self-control (e.g. own measurements, diary) as opposed to guiding and advice giving.

Keywords:

diabetes mellitus, diabetes apps, disease self-management, TAM 2

Introduction

Diabetes mellitus is a non-communicable metabolic disease affecting the population in high, intermediate and low-income countries [1,2]. Reflected by the high prevalence rates and forecasts predicting increasing prevalence rates for the upcoming years [3], diabetes will remain a significant challenge for the societies and health systems worldwide. Known causes for diabetes type 2 are excess body weight and physical inactivity, while the prevention and causes for diabetes type 1 are largely unknown [1]. Well managed blood glucose levels strongly depend not only on the medical therapy but also on the behaviour of the patients themselves. This embraces regular physical activity, an adapted balanced diet, achieving and maintaining a normal body weight, all of which cannot only help to prevent the disease but also help the patients to manage the disease and avoid reduced quality of life and further complications [2,4,5]. These insights were bundled by the concept of self-management, which does not apply to diabetes alone, and is defined as coping with everyday life with the disease, i.e., symptoms, treatment and lifestyle adjustment, on one's own [6]. Pursuing the motto "what gets measured gets done", patient self-management indicators include measures of health behaviors and patient-centered collaborative care. [7]. Diabetes apps can support these activities by documenting relevant data, blood glucose

monitoring or insulin administration (log data, diary apps), calculating values (blood glucose conversion), providing access to communities (forum), giving advice (nutrition, physical activity, clinical guidelines), gaming (quiz) and activities for children [8]. The apps appear to be particularly helpful with regard to the disease self-management by raising awareness of behavioural complications and thus increasing the self-competence of diabetic patients [9-11].

Assuming that apps are of utility in terms of disease self-management, theoretical frameworks predicting the perceived usefulness of these apps seem to be promising. One of the most known frameworks is the Technology Acceptance Model (TAM) [12] which has been expanded to TAM 2 including social and cognitive variables [13]. The main target variable for applying TAM in quantitative models was whether the disease management app was "intended to be used" [14] which corresponds with the classic TAM approach. Several qualitative or mixed methods studies also employed TAM to investigate barriers and facilitators of app use for self-care [15, 16]. Among the perceived benefits were greater self-awareness of one's condition, easier integration of self-management in daily life and the ability to view historical data without visiting a doctor [17]. However, the studies focusing more explicitly on self-management as the dependent variable were exploratory and did not use quantitative methods to test hypotheses. This did not apply to diabetes only but also to other diseases, e.g. COPD [18].

Against this background, the study aims to further investigate what circumstances contributed to perceiving an app as a beneficial tool for self-management. It, therefore, addresses the following research questions: a) How well can a TAM 2 model explain the variance of "perceived disease self-management" as a major benefit of using an app?, and b) Which TAM 2 variables contribute to such an explanation model?

Methods

A TAM 2 informed hypothesis model was developed to explain the degree of self-management support provided by diabetes apps (Fig. 1) that includes the TAM 2 variables "subjective norm", "image", "relevance", "experience", "perceived ease of use" and "perceived usefulness". "Relevance" addressed everyday life not the job as in the original version, "voluntariness" was combined with "subjective norm" as the use of the app was not mandatory and the "voluntary" use could only be limited by a strong recommendation from the attending physician or from the family, i.e. "subjective norm". This was considered when "subjective norm" was operationalised. Furthermore "output

quality" and "results demonstrability" were combined to "outcome quality" as the results of the app and the presentation of the data could often not be distinguished. The TAM 2 derived variables were supplemented by the type of the app "App classification" denoting whether the app was mainly used as a diary or measurement repository or whether it served as a system providing active advice in terms of nutrition, therapy or any other interventions. Demographic variables including type of diabetes, age and gender complemented the model.
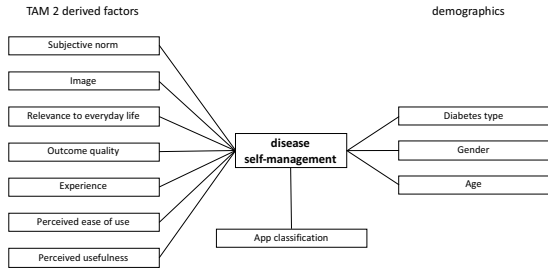

Figure 1 – Hypotheses model (bidirectional)

The model was operationalized and implemented in an online questionnaire realised in LimeSurvey. In order to check the validity and the technical implementation, a pretest was carried out among a representative group of participants (different age and profession, diabetics with and without handicaps). Based on the feedback various changes were made to the questionnaire. Table 1 shows the constructs together with a short definition and sample items. The final questionnaire contained a total of 37 items out of which 27 items were used in this analysis.

Table 1– Overview of the constructs measured incl. short definition and example item (a = 10-point numeric scale, b = dichotomous value), {number of items}

Construct	Definition	Sample item
Subjective norm {4}	Social pressure to use a diabetic app (from physician and/or family).	"I use the app because my physician strongly recommends it." [a]
Image {1}	Perceived increase in social status through the use of a diabetic app.	"As a diabetes app user, I take a modern and innovative approach to my condition." [a]
Relevance to everyday life {2}	Usefulness of a diabetic app for everyday life.	"The app provides me with more security and control over my condition in everyday life." [a]
Outcome quality {2}	Comprehensibility, accessibility, overview of the results achieved by using a diabetes app.	"The data is presented in a clear way." [a]
Experience {1}	usage per day	minutes per day
Perceived ease of use {10}	Satisfaction, learnability and system quality of the diabetes app used.	"It is very easy to learn how to use the app." [a]

Perceived usefulness {2}	Usefulness regarding the condition	"The diabetes app provides me all the data I need." [a]
App classification {1}	App type	therapy support, nutrition / exercise advice (0), diary / measurements (1) [b]
Diabetes type {1}		type II and other types (0), type I (1) [b]
Gender {1}		male and other (0), female (1) [b]
Age {1}	young/middle age vs. old	55 y. and younger (0), older than 55 y. (1) [b]
Disease self-management {1}	Perceived contribution to managing everyday life with the disease on one's own through the app use.	"I can change my behavior or adjust my therapy based on the data." [a]

Participants were recruited via email, Facebook and forums and addressed members of various major German diabetes support groups, interest groups and user groups of app providers. Data were collected from end of August to early November 2020. In order to classify the apps used by the participants, the app features were extracted from the websites of the app provider. Two persons checked the features and classified the app either as an app that primarily enables the "diary and measurement repository" functions or the "therapy support, nutrition and exercise advice" features. Therapy support included reminders, warnings, calculations, trends and predictions, therapy / diet and exercise information and advice. "Diary and measurement repository" functions embraced the classic diary, any sort of documentation and storing and displaying the blood glucose values that had been measured. This classification was mainly based on the information provided by diaDigital (https://www.diabetesde.org/diadigital), a joint working group of the major German scientific association (Deutsche Diabetische Gesellschaft), diabetes support groups and the association of diabetes advisers. Some of the apps had been classified by diaDigital already and served as examples for the classification of the other apps. Apps in the cluster "diet advice" were subsumed under the category "therapy support, nutrition and exercise advice".

Multiple linear regression was used to test the hypothesis model. To check the model assumptions, linearity, normal distribution of the residuals, independence of the residuals, homoscedasticity and multicollinearity were tested.

Results

A total of 386 people participated in the survey. Of these, 259 people used an app and 127 did not. Only the answers of app users were used in this analysis from which 24 did not provide any demographic information. Thus, answers from a total of 235 persons were finally included (Tab. 2).

Table 2– Demographics

	Gender	Age groups
Total (n=235; 100.0%)	male (n=113; 48.1%)	>41 years (n=63; 26.8%)
	female (n=120; 51.0%)	41-55 years (n=83; 35.3%)

	divers (n=2; .9%)	<55 years (n=89; 37.9%)
	male (n=55; 38.5%)	>41 years (n=56; 39.2%)
diabetes type 1 (n=143; 60.9%)	female (n=87; 60.8%)	41-55 years (n=47; 32.8%)
	divers (n=1; .7%)	<55 years (n=40; 28.0%)
	male (n=56; 65.1%)	>41 years (n=6; 7.0%)
diabetes type 2 (n=86; 36.5%)	female (n=29; 33.7%)	41-55 years (n=35; 40.7%)
	divers (n=1; 1.2%)	<55 years (n=45; 52.3%)
	male (n=2; 60.9%)	>41 years (n=1; 16.7%)
other diabetes types (n=6; 2.6%)	female (n=4; 60.9%)	41-55 years (n=1; 16.7%)
	divers (n=0; .0%)	<55 years (n=4; 66.7%)

The particpants used a total of 27 different apps that were classified into 15 "therapy, nutrition and advice" and 12 "diary and measurement repository" apps according to the method described above.

The predictors included in the regression model explained 59.2% of the variance in the perceived level of support for diabetes self-management by the app use (F=29.5; df=11,223; p<0.000).
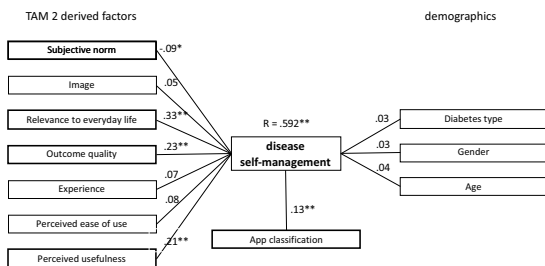

TAM 2 derived factors   demographics

*Figure 2 – Beta coefficients (** p<0.01; * p<0.05)*

Out of the TAM 2 informed variable, "subjective norm", "relevance to everyday life", "outcome quality" and "perceived usefulness" became significant showing that the higher these factors were (exception "subjective norm") the better they supported the perceived degree of disease self-management. In case of "subjective norm" with a negative coefficient the association was different and the more pressure there was the less was the app perceived as a help for self-management. Also, the type of the app played a significant role, apps with a diary and measurement storage functions were superior to apps with therapy, nutrition and intervention advice concerning self-management. None of the demographics factors were significant, meaning that neither age, gender nor diabetes type were associ-

ated with better or worse perceived support of the app for managing the disease. Alike, "experience", "image" and "perceived ease of use" were not significantly associated. Figure 2 shows the findings in the hypothesis model.

Discussion

This study investigated which factors explain the perceived degree of disease self-management support of diabetes apps. The overall model accounting for 59.2% of the variance was not only statistically significant but also satisfactory regarding the absolute level of explanation. This result indicates the general usefulness of a TAM 2 guided approach to model app use for perceived diabetes self-management. In the past, TAM 2 related quantitative models had been primarily used to predict "behavioural intention" to use an app for disease management, e.g. obesity [14].

The predictors "everyday relevance", "outcome quality", "perceived usefulness" and "app classification" showed a positively associated and highly significant (p < 0.01) influence on perceived disease self-management. This demonstrates that all variables touching a) relevance, b) usefulness and c) outcome quality in terms of the results displayed and produced by the app, determine the degree to whether an app is perceived as a good tool for self-management. This can be called the relevance-usefulness-quality complex. Furthermore, the study revealed that instigation of others particularly family members or the physician ("social norm") had a negative effect on the perception of the app. In the same vein, apps predominantely serving as diary and measurement apps were preferably regarded as useful self-management tools contrasting advice apps. While the first type of apps offer features that the patients themselves control the latter type of apps tend to act as an external instance imposing information on the app users. Both factors, refusing "social norm" and apps allowing the control over what the app does could be summarized by "self-control" or "autonomy".

The preference of diary and measurement apps compared to advice apps might be surprising because providing information on nutrition, physical activity, clinical guidelines belongs to the features of quite a number of apps [8], which was also reflected by the number of apps of this type in our study (15 vs. 12). Furthermore, any kind of advice might be seen as a supportive element. In fact, self-management support [19] is regarded an important principle within the chronic care model to actually empower the patients to care for themselves. It is closely related to self-management education [7], another pillar of patient empowerment.

However, it is also well known that patients with chronic diseases like diabetes are experts themselves ("expert patient") that had been trained and have an understanding of what is best for them [20]. For this type of patients having up-to-date blood glucose values and reflecting their symptoms and behaviour in a diary could be fully sufficient to manage the symptoms. Then self-management would be really self-management and the patients would be proficient enough to cope with their disease. This interpretation is supported by [17] that summarized the benefits among others as greater self-awareness of one's condition and the ability to view historical data without visiting a doctor.

This would change the perspective on "self-management" and "patient-centeredness" from a paternalistic view to an empowered view. In fact, not only patient-physician interaction but also patient-app interaction has to be evaluated. The four model

scheme of paternalistic, informed, interpreted or deliberated relations describing patient-physician interactions [21] could serve as a blue print.

Whether the participants in this study were experts in self-management was not captured by the questionnaire. Alike, although self support groups were strongly involved when recruiting study subjects, this is no final clue about the expert status of the participants. Furthermore, this study investigated the perceived degree of self-management, not an objective measure of self-management behaviour. So there is no information on how well the participants managed their disease.

This study faces also some other limitations, particularly with regard to the self-selection of the sample and the variable "app classification". Classifying an app either as primarily supporting "diary and measurement repository" functions or the "therapy support, nutrition and exercise advice" features was not easy because many apps had mixed functionality. However, the classification rationale was based on an existing scheme. Furthermore, two persons performed the classification and finally agreed on the current coding.

In the same vein, other features of apps have to be monitored closely for future studies in order to capture new functions. The apps in this study had virtually no means to establish a meaningful contact with the physician or other providers. However, studies point to the importance of exactly this added value [15] because self-management does not imply "to be left alone".

In summary, the present study investigated TAM 2 informed factors determining app supported perceived diabetes self-management testing a regression model. Factors belonging to the relevance-usefulness-quality complex as well as factors reflecting self-control were found to significantly explain the variance of self-management. Other factors describing the patients, i.e. age, gender, app experience and type of diabetes were found to be insignificant. Neither did image or perceived ease of use play a significant role.

Conclusions

Apps have been attested to empower patients regarding their disease self-management through numerous studies. The present study makes a contribution to the scientific discussion by suggesting factors that are particularly associated with self-management. It hereby raises the question whether apps should be designed to strengthen self-management in the sense of self-control and patient autonomy (e.g., own measurements, diary) as opposed to guiding and advice giving. Expressed in other words, "Should app self-management mean *self*-control?".

This study does not give a conclusive answer, however, points to the need of further studying the relationship between the patient and the app depending on the patient needs.

Acknowledgement

References

[1] World Health Organization. *Diabetes*. Geneva, Switzerland: April 13th, 2021.

[2] World Health Organization. *Global report on diabetes.* Geneva, Switzerland: World Health Organization; 2016.

[3] W.R. Rowley, C. Bezold, Y. Arikan, E. Byrne, S. Krohe. Diabetes 2030: Insights from Yesterday, Today, and Future Trends. *Popul Health Manag* **20** (2017),6–12.

[4] B. Hemmingsen, G. Gimenez-Perez, D. Mauricio, M. Roqué I Figuls, M.I.Metzendorf, B. Richter. Diet, physical activity or both for prevention or delay of type 2 diabetes mellitus and its associated complications in people at increased risk of developing type 2 diabetes mellitus. *Cochrane Database Syst Rev.* **12(12)** (2017). doi: 10.1002/14651858.CD003054.pub4.

[5] J.S. Haw JS, K.I. Galaviz, A.N. Straus, A.J. Kowalski, M.J. Magee, M.B. Weber, J. Wei, K.M.V. Narayan, M.K. Ali. Long-term Sustainability of Diabetes Prevention Approaches: A Systematic Review and Meta-analysis of Randomized Clinical Trials. *JAMA internal medicine* **177**(12) (2017), 1808–1817. doi.org/10.1001/jamainternmed.2017.6040.

[6] V.J. Barr, S. Robinson, B. Marin-Link, L. Underhill, A. Dotts, D. Ravensdale, S. Salivaras. The expanded Chronic Care Model: an integration of concepts and strategies from population health promotion and the Chronic Care Model. *Hosp Q.* **7**(1) (2003),73-82. doi: 10.12927/hcq.2003.16763.

[7] R.E. Glasgow, M. Peeples, S.E. Skovlund. Where is the patient in diabetes performance measures? The case for including patient-centered and self-management measures. *Diabetes Care* **31**(5) (2008),1046-50. doi: 10.2337/dc07-1845.

[8] N. Brew-Sam, A. Chib. How Do Smart Device Apps for Diabetes Self-Management Correspond with Theoretical Indicators of Empowerment? An Analysis of App Features. *International Journal of Technology Assessment in Health Care*. **35** (2019), 150–159. doi.org/10.1017/ S0266462319000163.

[9] M.M. Kebede, T.P. Liedtke, T. Möllers, C.R. Pischke. Characterizing Active Ingredients of eHealth Interventions Targeting Persons With Poorly Controlled Type 2 Diabetes Mellitus Using the Behavior Change Techniques Taxonomy: Scoping Review. *Journal of medical Internet research* **19**(10) (2017), e348. doi.org/10.2196/jmir.7135.

[10] G.R. Husted, J. Weis, G. Teilmann, P. Castensøe-Seidenfaden. Exploring the Influence of a Smartphone App (Young with Diabetes) on Young People's Self-Management: Qualitative Study. *JMIR mHealth and uHealth* **6** (2) (2018), e43. doi.org/10.2196/mhealth.8876.

[11] S. Veazie, K. Winchell, J. Gilbert, R. Paynter, I. Ivlev, K.B. Eden, K. Nussbaum, N. Weiskopf, J.M. Guise, M. Helfand. Rapid Evidence Review of Mobile Applications for Self-management of Diabetes. *Journal of general internal medicine* **33**(7) (2018),1167–1176. doi.org/10.1007/s11606-018-4410-1.

[12] F.D. Davis. Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly* **13**(3) (1989), 319–340. doi.org/10.2307/249008.

[13] V. Venkatesh, F.D. Davis. A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies. *Management Science* **46** (2) (2000), 186–204. doi.org/10.1287/mnsc.46.2.186.11926.

[14] E. Jeon, H.A. Park. Factors affecting acceptance of smartphone application for management of obesity.

Healthc Inform Res. **21**(2) (2015),74-82. doi: 10.4258/hir.2015.21.2.74.

[15] B. Jeffrey, M. Bagala, A. Creighton, T. Leavey, S. Nicholls, C. Wood, J. Longman, J. Barker, S. Pit. Mobile phone applications and their use in the self-management of Type 2 Diabetes Mellitus: a qualitative study among app users and non-app users. *Diabetol Metab Syndr.* **11** (2019), 84. doi.org/10.1186/s13098-019-0480-4.

[16] M. O'Neill, C. Houghton, G. Crilly, M. Dowling. A qualitative evidence synthesis of users' experience of mobile health applications in the self-management of type 2 diabetes. *Chronic illness*, (2021). doi.org/10.1177/1742395320983877.

[17] K. Anderson, O. Burford, L. Emmerton. Mobile Health Apps to Facilitate Self-Care: A Qualitative Study of User Experiences. *PLoS One*. **11**(5) (2016),e0156164. doi: 10.1371/journal.pone.0156164.

[18] L. Knox, R. Gemine, S. Rees, S. Bowen, P. Groom, D. Taylor, I. Bond, W. Rosser, K. Lewis. Using the Technology Acceptance Model to conceptualise experiences of the usability and acceptability of a self-management app (COPD.Pal®) for Chronic Obstructive Pulmonary Disease. *Health Technol (Berl)*. (2020), 1-7. doi: 10.1007/s12553-020-00494-7.

[19] E.H. Wagner, B.T. Austin, C. Davis, M. Hindmarsh, J. Schaefer, A. Bonomi. Improving chronic illness care: translating evidence into action. *Health Aff (Millwood)* **20**(6) (2001), 64–78 10.1377/hlthaff.20.6.64

[20] H.D. McIntyre. Dose adjustment for normal eating: a role for the expert patient? *Diabetes Metab J.* **38**(2) (2014), 87-91. doi: 10.4093/dmj.2014.38.2.87.

[21] EJ Emanuel EJ, LL Emanuel. Four models of the physician-patient relationship. *JAMA*. **267**(16) (1992), 2221-6.

Address for correspondence

Lukas Reineke c/o Ursula Hübner, PhD, FIAHSI, Osnabrück University of AS, Health Informatics Research Group, PO Box 1940, 49009 Osnabrück, Germany; E-Mail: u.hübner@hs-osnabrueck.de.